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STEM Education: Understanding the Effects of Student Interest in Science Using the 5E Learning Model

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Abstract

This study examined student engagement in sixth-grade science using the 5E Learning Model. A qualitative research approach was used to explore the effectiveness of the 5E learning model compared to the inquiry-based learning model used to integrate STEM within the sixth-grade science classroom. Data was gathered through observations, time on task, and journals. The participants were made of two 6th-grade science classrooms: Class A, the control group, had thirteen participants, and Class B, the experimental group, had eleven participants. The journals and observations were transcribed and analyzed. The results showed that students in the experimental group who used the 5E model were more engaged than students who learned through the inquiry-based model. The effectiveness of the 5E learning model curriculum in sixth grade will help teachers understand the challenges of integrating STEM into the science curriculum.

Introduction

During the 21st century, the combination of Science, Technology, Engineering, and Mathematics (STEM) education has become prominent in K12 classrooms throughout the United States and worldwide. STEM is a rich interdisciplinary field combining science, technology, engineering, and mathematics. Adopting the Next Generation Science Standards (NGSS) has given researchers and teachers a platform for introducing STEM in early elementary grades. According to Wu-Rorrer (2017), "There is no single strategy for approaching STEM integration. No School or school system is the same." (p. 8-9). Therefore, the purpose of the research study was to examine the extent of students' engagement in the STEM curriculum through the use of the 5E Learning Model and the resources used within the model. Considering there is not one single strategy known to work best when implementing STEM, identifying the advantages and disadvantages of the 5E model could help guide elementary teachers' STEM strategies in the future.

During the last decade, there has been a high demand for jobs requiring a combination of science, mathematics, technology, and engineering skills. However, individual states' science standards still need to address the needs of this high demand. Florida Tech News states that "companies in STEM fields are engaged in constant research and development to continually advance technologies further, which will only lead to more growth and need for more workers to implement these new ideas and bring them to fruition" (Florida Tech News 2018, para 2). Consequently, the Next Generation Science Standards (NGSS) aim to meet the high demand for science, mathematics, technology, and engineering teachers and prepare students for careers in these fields. According to the NGSS website, “a high-quality science education means that students will develop an in-depth understanding of content and develop key skills- communication, collaboration, inquiry, problem solving, and flexibility-that will serve them throughout their educational and professional lives” (NGSS 2018, para. 3). By analyzing student engagement when implementing the 5E model compared to the inquiry-based learning model, we identified helpful teaching strategies and resources that fully engage students in STEM education.

This study aimed to explore student interest levels using the 5E Learning Model when implementing STEM into the sixth-grade science classroom. This research study provided evidence that supports the use of the 5E model at any grade level. Addressing the issue of further implementing the 5E Learning Model into elementary classrooms is essential to understanding teachers’ methodology when teaching science and implementing STEM. Fantz and Katsioloudis (2011) summarize that college students in elementary programs take minor coursework in engineering. Also, programs tend to focus on the teaching methods instead of digging deeper into the science and engineering content. Using this study to understand how the 5E model and resources affect students’ interests allows school districts to adopt this teaching practice and ensure students receive quality lessons within the science curriculum.

This qualitative study is essential to understand how the 5E model engages and motivates sixth-grade students within the STEM curriculum. Most of the literature reviewed addresses the need for teachers to enhance STEM within their classrooms but needs to address how to incorporate those lessons into their classrooms. Teacher observations using key identifiers were used throughout a 5E learning model and inquiry-based science lessons to understand student engagement better. Collecting data from the 5E learning model and the inquiry-based science lesson allowed the data collected to be compared to identify any changes in student engagement and motivation between the two learning models.

There are multiple benefits to researching the impact of the 5E model and its resources. The positive effects of the 5E model demonstrated in sixth-grade science allow curriculum directors to understand and implement a STEM curriculum in all grade levels. This will enable teachers to assess their practices and determine what works best for students to continue to be engaged in STEM. Students benefit the most from this research as students are exposed to a new understanding of learning material through phenomena and real-world problems. Lessons used through the 5E model are student-driven. German (2017) explains that the NGSS's importance is having students interact with phenomena and real-world problems using problem-solving and engineering practices. In return, when the teacher carefully constructs the 5E model, each lesson is driven by student questions and investigations.

The central research question that this study answered was: how will the implementation of the 5E learning model compare to the inquiry-based learning model used to affect student engagement within the sixth-grade science classroom? This study also addressed the following sub-questions:

(1) How does the 5E model compare to inquiry-based learning when addressing student engagement?
(2) How is student engagement affected within the STEM curriculum when comparing male and female students?

Literature Review

In the past, academic fields such as Science, technology, engineering, and mathematics were, to a large extent, separate entities with minor overlap in teaching and research. With the introduction of the Next Generation Science Standards, K-12 teachers, researchers, and academicians have been given a new set of standards to address science, technology, engineering, and mathematics integration into the science curriculum. The purpose of the NGSS is for teachers to create interdisciplinary lessons that use all four areas of study in one unit. The shift from individual state science standards to NGSS allows teachers to support the growing professions, focusing on each STEM part.

Employment in STEM-related professions is expected to grow by 17 percent in 2018 (Langdon, McKittrick, Beede, Khan, & Doms, 2011). By 2025, the US Manufacturing Institute and Deloitte estimate that two million manufacturing jobs utilizing STEM skills will go unfilled due to a lack of interest, exposure, and skills (Giffi, Dollar, Drew, McNelly, Carrick, & Gangula, 2015). To close the gap between unfilled STEM positions and STEM education, this research study investigated how STEM lessons are implemented and assist future educators with strategies to incorporate science, technology, engineering, and mathematics as one entity within K-12 classrooms. According to Kennedy, “developing and supporting robust STEM programs help schools and universities attract students to pursue studies in those fields and providing facilities specifically designed to enhance the effectiveness of STEM instruction enables those students to make the most of their education opportunities” (Supporting STEM 2018, para. 19).

Incorporating STEM into the science disciplines is crucial for preparing students for the future and motivating and engaging them to learn science more authentically. A recent study at Brentwood Magnet Elementary School of Engineering found that students struggled in science on state tests. Teachers worked together to plan collaboratively, create innovative solutions, and ask questions within their classrooms. Implementing STEM into their school dramatically improved students’ interests and test scores (Hardee, 2015). Many people from the STEM profession believe in including STEM within our curriculums. Laros (2016) states, “We need to focus our efforts on getting more kids, particularly women and African-Americans, interested in pursuing STEM at a young age” (Engineering.com, para. 7). However, many elementary teachers do not feel comfortable teaching science. Trygstad (2013) states that most elementary teachers feel out of their comfort zone when teaching science. Research shows that elementary teachers do not have adequate training to incorporate and teach engineering skills articulated in the NGSS (The National Research Council, 2015). Therefore, this study is essential to identify strategies teachers can use to teach engineering design and skills of the NGSS and develop themes that will help future elementary teachers implement STEM within their classrooms.According to Creswell, J. W. and Creswell, J. D. (2018), STEM can be introduced into any classroom with various approaches. A social constructivist who believes students can make meaning of the world around them and connect to build on prior knowledge may use the 5E model (p. 7). The 5 E model can be used at any age level. The 5 E model may be tailored to that specific grade at each age level when broken down into five parts.

The 5 E model begins with the “Engage” stage. This stage aims to help learners connect new information and past learning experiences throughout the model. This stage should be one of the most critical stages for a teacher to plan. This stage draws the students in and gives them a purpose around the unit and lessons. During the 2015-2016 school year, New York City teachers participated in an experimental study using a playground physics program to engage students in physics concepts. In the end, data supported those students whose teachers implemented playground physics to teach physics concepts understood the physics concepts better than the students whose teachers used a traditional physics curriculum (Friedman, L.B., Margolin, J., Swanlund, A., Dhillon, S., Liu, F., 2017). Engaging students in topics relevant to their lives and ones they can build upon can help them stay engaged throughout the 5E learning cycle.

After the engage stage, students are then introduced to the “Explore” stage. During this stage, students investigate one key lesson and explore materials related to the unit within this stage. During this stage, students should consider how they will explain their findings from the lesson or materials. The explain phase follows the “Explore” stage. In this stage, students find ways to explain their findings. Students can use a variety of ways to display and demonstrate their findings through presentations or models.

The final two stages of the 5E model go hand in hand with each other. Following the “explain” stage, teachers will allow students to “Elaborate.” Within the elaborate stage, students will deepen their understanding of the significant concepts outlined within the 5E learning cycle. Students would use this phase to gain more information in a specific area of interest or improve their skills used within another phase. Teachers might use this phase as a culminating project where students use parts of each phase to demonstrate their knowledge. The 5E model is wrapped up with the “Evaluate” phase. This is where teachers and students evaluate their understanding of the concepts investigated. During this phase, students must self-assess themselves to see where they can improve and grow with their learning in the next 5E model.

While research on implementing the 5E model is limited, many ways exist to introduce STEM education within a classroom. Students could benefit from the 5E model because they would be exposed to STEM. One benefit of the 5E model is that each phase can be modified to work with any grade or academic level. An additional explore phase can be added before the elaborate phase to expose students to another essential question or phenomenon within the learning cycle.

Methodology

The overall design of this research project used a qualitative approach. A case study approach compared the 5E learning model to the inquiry-based learning model, student engagement, and male students versus female students’ engagement. “The case study approach allows in-depth, multi-faceted explorations of complex issues in their real-life settings” (Crowe, S., Cresswell, K., Robertson, A., Huby, G., Avery, A., and Sheikh, A, 2011, NCBI para. 1). The case study approach provides students a rich understanding to research questions through the journaling and direct observations.

A multi-case study approach was also used to collect data needed to investigate the research question and sub-questions. Using this approach was important in the data collection process because Creswell & Creswell (2018) explain,

> Case studies are a design of inquiry found in many fields, especially evaluation, in which the researcher develops an in-depth analysis of a case, often a program, event, activity, process, or one or more individuals. Cases are bounded by time and activity, and researchers collect detailed information using a variety of data collection procedures over a sustained period of time (p. 14).

Through a case study design, the science curriculum and activities used within the curriculum were assessed and analyzed to evaluate student engagement.The research occurred in two 6th-grade science classrooms in a rural school district in central Illinois. This grade level was chosen because the 6th-grade students had not been exposed to the 5E learning model before this study. During the implementation of the study, the 5E learning model was introduced to a group of students who needed to gain experience in this learning style; therefore, the data collected was not influenced by any prior experiences.

The study focused on two separate 6th-grade classes. The two classes that are a part of the study were referred to as Class A and Class B. Class A has a total of thirteen students, seven boys, and six girls. Class B had eleven students, seven boys and four girls. Class A was the control group, using an inquiry-based learning approach. Class B was the experimental group where the 5E learning approach was implemented. The data collected through observations and journaling was compared and analyzed using the two different teaching approaches in two separate classes.Open-ended Observations were used to collect data to measure the extent of student engagement within both the inquiry-based and 5E learning models. This form of data collection allowed the researcher to support data written in the journal.

Another form that was used to collect data was called a time-on-task form. This form addresses six different data points while instruction is taking place. Data was collected every five minutes throughout each lesson. The researchers observed the whole class and analyzed if the entire class was on task or off class. To address the research question of male student engagement versus female student engagement, the time on task form also addressed time on and off class for both genders. Additionally, data was collected through journaling for Class A and Class B. Journaling took place at the end of each class. The journals addressed a lesson description, student engagement, and reflection on the lesson based on the method used. Thoughts and feelings about the lesson were included to determine the effectiveness of the inquiry-based and 5E models. The open-ended observation form and time-on-task form were referenced to complete each journal.The data collected through the observations, journals, and time on task was coded. According to Creswell and Creswell (2018), The coding process was intended "to generate a description of the setting or people as well as categories or themes for analysis" (p. 194). This process ensures that accurate coding procedures authenticate the data collected through the interviews and observations. During the data analysis stage, narrative passages were developed to communicate the themes that emerged from the data.

The central research question addressed in this study was, how will implementing the 5E learning model compare to the inquiry-based learning model used affect student engagement within the sixth-grade science classroom? This study also addressed the following sub-questions:

1. How does the 5E model compare to inquiry-based learning when addressing student engagement?
2. How is student engagement affected within the STEM curriculum when comparing male and female students?

Several limitations could have impacted the data collected from each class. Both classes have diverse students in terms of their abilities within the classroom. Students' abilities may have affected how the students reacted to each lesson and the teaching approach used. Although the students put into each class cannot be controlled, the data collected from each class was used to identify student engagement and male versus female engagement and compare inquiry-based teaching methods and 5E methods.

Results

The data gathered from time-on-task observations and journals throughout each lesson during the 5E and inquiry-based units was analyzed for common themes when comparing the two teaching practices. Time-on-task observations were divided into the whole class and male/female comparisons. To ensure the validity of the data, the same time-on-task tools and journaling were used for both study groups each day.

Results: Class A- Control Group: Inquiry-Based Learning

This study aimed to identify the impact of implementing the 5E learning model within units in sixth-grade science on student interest. The control group used lessons within the unit that have been used for years, not outlining the 5E learning model. The control group would provide baseline data to show student engagement within each lesson in the unit and used to compare to Class B, the experimental group. Data was collected using a time-on-task document and through daily observations that were documented each day. Data was broken down using each lesson that was taught. Some lessons took longer than one class period and are noted in each analysis for each lesson.

Inquiry-Based Guided Notes/Debate Poster: Lesson- Uniformitarianism vs. Catastrophism

The control group, Class A, completed guided notes that covered uniformitarianism and catastrophism. Definitions were given to the students, and a class discussion checked for understanding of the topics. When completing guided notes, students copied from the board. After students completed the guided notes, students were given a small mini-project to create a debate poster announcing the debate between uniformitarianism and catastrophism. Students were given four full class periods to work with a partner on their debate poster. Students were required to demonstrate their knowledge from the guided notes by designing the poster of uniformitarianism and catastrophism. Data was analyzed for Class A using time on task when students were completing class notes and working on their debate posters. Figure 1 identifies that students completing posters with partners were more engaged than those participating in guided notes. Although students in Class A did not demonstrate prior knowledge through the guided notes and class discussion, students used prior knowledge through their drawings to support the debate between uniformitarianism and catastrophism.

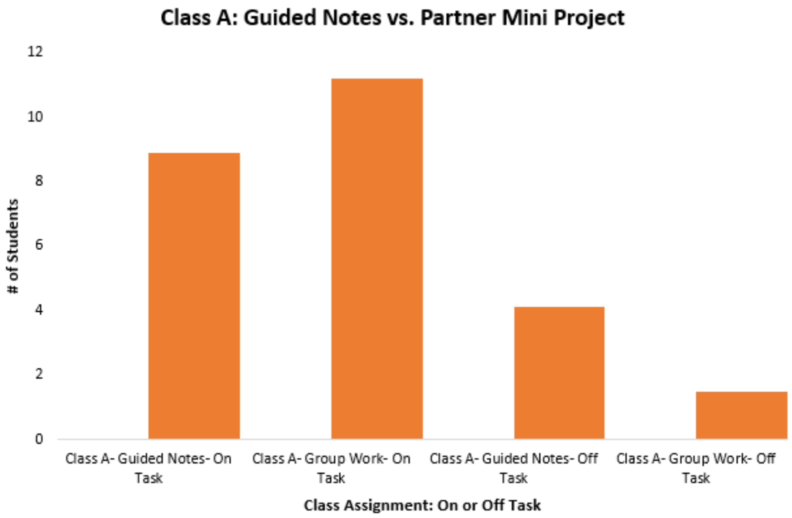

Figure 1. Class A: Guided Notes vs. Partner Mini Project

Inquiry-Based: Modeling Faults & Intrusions Lab

After Class A completed the debate posters, they moved on to a faults and intrusions lab. This extension of the prior lesson would help students understand how plates move. Students worked with partners during this lab. They identified tilt, fold, and intrusion when manipulating clay, which represented layers of rocks. Students stayed on task throughout the lesson and worked well with their partners. During the class period, an average of 10.8 out of 12 students were on task. A class discussion about their findings was held after the lab was complete. Students could identify each of the movements and demonstrate through hand motions. Students could also use their knowledge about plate movement to support their findings. Although student engagement was lower than when completing the debate posters, Figure 2 shows that students were more engaged through the lab than when completing guided notes.

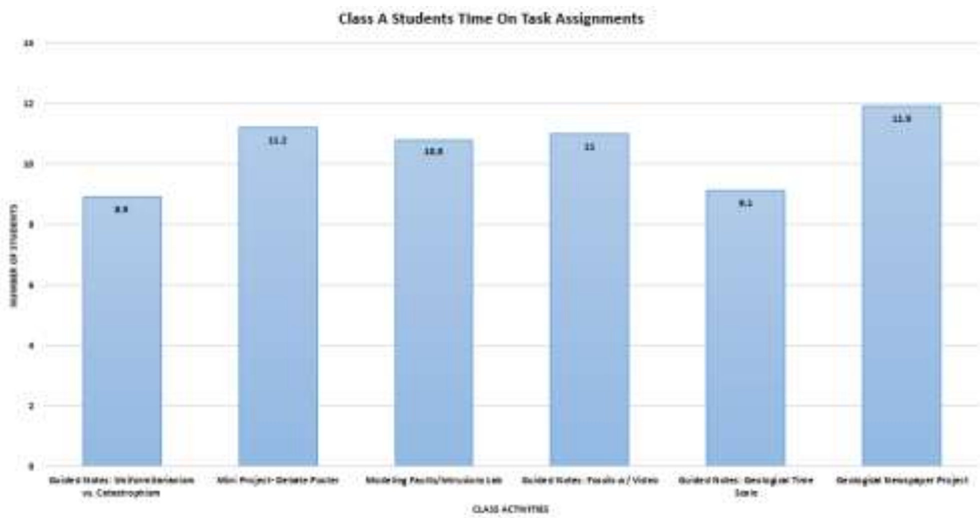

Figure 2. Class A Students Time on Task Assignments

Inquiry-Based: Guided Notes- Looking at Fossils w/ Jurassic Park Video Clip

Students completed guided notes that discussed how organisms can be fossilized and the types of scientists that study them. At the beginning of the lesson, students were not engaged, and I had to wait to get their attention. To start the lesson, students viewed a clip from Jurassic Park demonstrating how organisms are fossilized. During the video clip, all students were engaged and paying attention.

After the clip, students participated more throughout the guided notes and class discussion. Students used evidence from the video to support their reasoning. Students were asked to refer back to parts of the video to demonstrate their explanation during our class discussion. For one class period, an average of 11 out of 13 students were engaged. Most engagement happened after students viewed the video clip and guided notes.

Inquiry-Based: Guided Notes- Geological Time Scale Notes

Students completed guided notes that covered the geological time scale. Each division was discussed, but the focus of the notes was on the main eras of the geological time scale. Students needed to understand the eras to complete the final project. Through observations, students had difficulty staying on task and engaged throughout the guided notes. This section was very lengthy and required extensive writing. With two students absent that day, 9.1 out of 11 were on task. I tried to motivate students with the understanding that this would help them on their final project. This lesson did not have any videos or hands-on activities. Figure 2 identifies that students were less engaged in the two sets of guided notes that did not include supplemental activities.

Inquiry-Based: Geological Time Scale Newspaper Project

This was the final culminating project for the unit. Students had to create a front-page newspaper using a publisher, which announced the end of one era and the beginning of another. Students were to find three facts for each era that focused on geological, biological, and climatological changes within the eras. Students worked on this project independently and began researching, using a graphic organizer, and then organized their information on a newspaper cover they designed. Throughout the class time for this project, an average of 11.9 out of 13 remained on task. During observations, students were engaged, and few found more than the required facts. Students were more engaged when creating their newspaper designs than researching. Figure 2 recognizes that students were most engaged when completing the final project.

Results: Class B- Experimental Group: 5E Learning Model

Class B, the experimental group, consisted of eleven students, seven males and four females. This class participated in lessons that outlined the same unit as Class A but used the 5E learning model. Data was collected using time on task and observations that were documented each day. The data collected was analyzed and organized by each of the 5E sections.

5E Learning Model: Engage 1: Uniformitarianism vs. Catastrophism

Throughout Engage 1, the experimental group, Class B, completed a picture/video analysis. The analysis aimed to have students recognize, on their own, how formations within our world have formed. When students finished the analysis, the researchers wanted them to be able to define uniformitarianism and catastrophism by using supportive data from their analysis. While the anticipation was to use two class periods for this lesson, the students took three class periods to complete. Day 1 focused on the pictures, day 2 focused on the analysis of the videos, and day 3 was a class discussion about the students' findings.

For the three days, an average of 9.1 to 11 students remained on task throughout the entire class period. Through observations, students commented on the assignment and how they were thrilled not to do guided notes. However, the picture/video analysis was more work than the guided notes. Students were engaged through the videos and asked to view them several times to answer all the follow-up questions accurately. The level of student engagement throughout the three days led to a class discussion that was well thought out, supported, and participated by most students.

5E Learning Model: Explore/Explain: Personal Timeline

For the personal timeline representing the explore phase, students were required to complete a personal timeline that plotted one sports event, one geological event, one historical event, and seven events within their lives. Students used a graphic organizer to organize all their data before putting it on their timeline, representing the explain phase of the 5E learning. This assignment aimed to have students understand the process of their life timeline and relate it to the geological timeline. Throughout the six days, students had to complete the entire project. On average, 9.1 out of the 11 students remain engaged throughout the class period. However, student interest decreased towards the last two workdays. Figure 3 demonstrates the decrease in student engagement within the workdays provided. Through observations, students' time on task decreased because few completed the assignment. After all, time on task was calculated for the whole class regardless of their time to complete the assignment.

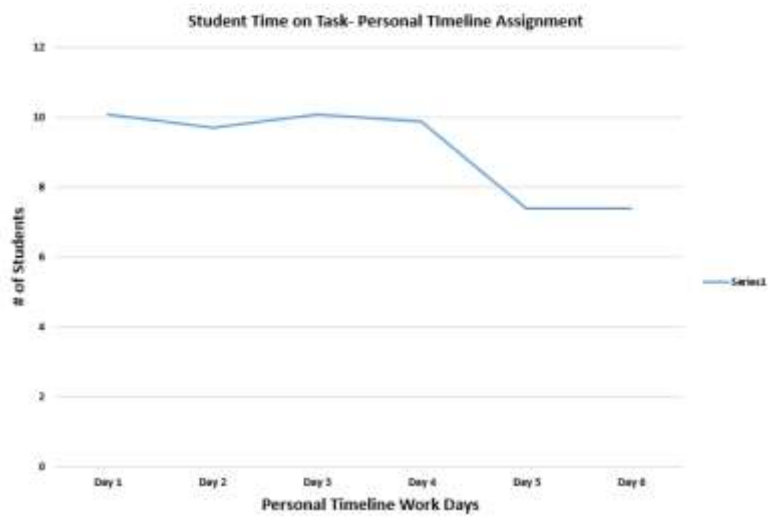

Figure 3. Time on Task: Personal Timeline Assignment

In the explain phase, students took their data collected through the explore phase and displayed it on a personal timeline. The personal timeline was displayed on a timetable created individually by each student using their traced arm's length. Students mathematically had to calculate an accurate scale to display their data. The administration made observations for evaluation purposes. Observations stated that students remained engaged throughout the design of their timelines.

5E Learning Model: Elaborate/Evaluate: Travel Agent Project

The elaborate phase of the 5E learning model required students to become travel agents to research and design travel information for each of the eras within the geological timeline. Students worked with partners, and there was one group of three. Students were required to research each era. Like Class A, Class B researched geological, biological, and climatological features for each era. However, Class B also investigated the different periods within the era, specific plants, and continental movement. The graphic organizer designed for Class B required more detailed and specific facts than for Class A. Throughout the five days, those students had to complete the assignment, an average of 9.8 out of 11 students remained on task for the class period. Through observations, students were eager to complete the assignment with partners. Although the research required more work than Class A, students could complete all parts of the research with the help of each other.

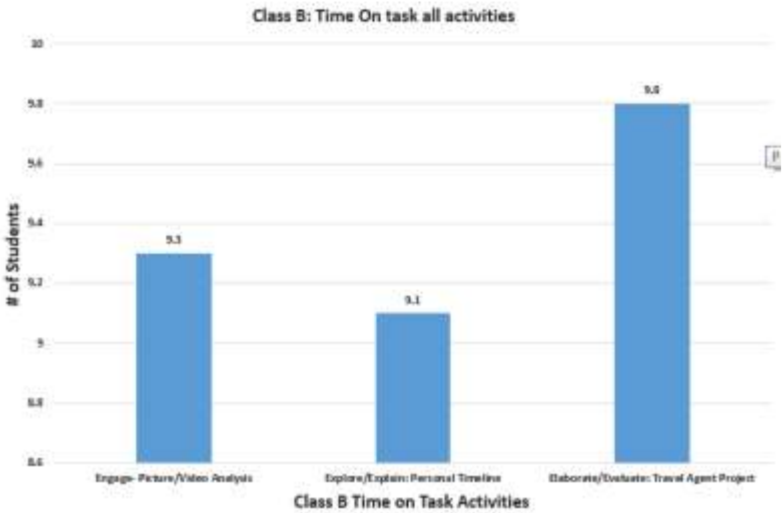

Figure 4. Class B: Time on Task All Activities

For the final evaluation phase within the 5E learning model, students displayed their travel agent project to be observed by other students. Projects were displayed with cups in front of each project. Students from other classes, including Class A, were allowed one ticket to put in the project cup they would use to travel to the different eras. Students were also given a sheet to document one thing they liked about the project and one thing they would improve. The students also assessed themselves, using the feedback from their peers, while the teacher assessed them. Through peer reviews, self-assessments, and teacher assessments, students understood where they excelled in their project and which areas could have improved. Several students wanted to take the feedback and change their projects to improve their grades. Figure 4 identifies that more than 9 of 11 students were on task for all 5E learning lessons.

Student Interest: Male vs. Female Students

While student interest was the focus of the research, breaking the research down further to identify if student interest was different for male versus female students was also analyzed. Data was collected using the time-on-task document. However, when data was analyzed, no evidence demonstrated that student interest was affected by gender. Further data could be collected using gender and diversity to identify if student interest is affected. This study focused on the overall class, including male and female students.

Conclusion

Class A, the control group, completed the Fossils Unit using an inquiry-based model. The data collected through time on task and observations demonstrate that Class A was less engaged than the experimental group who received the material through the 5E learning model. Class A was the least engaged through guided notes. There were three separate times students were taught the concepts through guided notes. In the fossils' notes, students began guided notes with a video from Jurassic Park. Students in Class A were more engaged in the guided notes with the video than in the notes without any other supplemental support.

Although Class A displayed a lower percentage of student engagement through the time on task on guided notes, student engagement increased during the lab and final project. The lab and final project allowed students to justify understanding independently. "Learning science is an active process that includes both individual and social processing." (Scott et al., 2014, p. 49). The lab allowed students to process their understanding of plate movement socially, and the final project allowed students to process the concepts needed to complete the newspaper individually. While these activities did not happen in succession, data supports that those students from the control group were most engaged during this time.

Class B, the experimental group, completed the Fossils Unit using the 5E learning model. Data supports that the students who used the 5E learning model were more engaged throughout the duration of the unit than the students from Class A. Students showed the most engagement in the elaborate phase of the 5E model. This phase can be comparable to the final project in Class A. Class B was required to complete more research but was allowed to work with partners.

Through observations, working with partners increased student's engagement in the elaborate phase. Overall, the data collected supports that the students who completed the Fossils Unit through the 5E learning model were more engaged throughout the unit than in Class A. Although data supports the 5E learning model, several activities completed in Class A had students engaged. Further research would need to be completed to continue to evaluate the effectiveness of the 5E learning model. With the support of the data collected, continued evaluation of the process will be further implemented in the 6th-grade science curriculum.

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